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Effect of Iron Nutrition on the Yield, Chlorosis, Fruit Quality and Leaf Composition of Acidlime Trees Grown on Loamy Sand Soils*

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ABSTRACT

A field experiment was conducted to find out effectiveness of application of inorganic sources of Fe and S to alleviate iron chlorosis in acidlime of trees, cultivar *Kagzilime* (*Citrus aurantifolia*, Swingle) grown on a loamy sand soil. Iron and S were applied to the soil as sulphates, oxides and elemental form individually in twelve different treatments. The fruit yield and fruit quality were improved in all treatments as compared to the control. Ferrous sulphate (108 g Fe/tree), sulphuric acid (719 and 1439 g S/tree) and elemental sulphur (1800 g S/tree) treatments gave significantly higher fruit yield and improved the quality as compared to the control due to higher recovery of iron chlorosis. These treatments had also significantly increased the Mg, S, total Fe, Mn and Zn content in leaves. With increasing availability of sulphur, there was increased turnover of Fe^{2+} ions for chlorophyll synthesis.

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INTRODUCTION

Acidlime (Cultivar-*Kagzilime*) has attained the commercial status throughout India. The seedlings of *Kagzilime* are successfully grown under loamly sand soils of North Gujarat, but interveinal chlorosis is common occurrence. The soil factors reported to have caused Fe deficiency include high soil pH, high CO_3^{-2}, HCO_3^- in alkaline soils of arid and semiarid regions and high P concentrations (Tisdale *et al.*, 1990). The plant factors include alkaline nature cell sap; low active iron, low concentrations of organic compounds like citrate involved in its translocation, high P concentration, high metallic micronutrient concentration, imbalances in nutrient rations involving Fe and factors relating to enzymatic activities associated with Fe utilization (Ronald, 1987). The present investigation was undertaken into objecting to assess various sources of Fe for longterm prevention of Fe-chlorosis and effect on the yield and fruit quality of *Kagzilime* grown on loamy sand soil.

MATERIALS AND METHODS

An experiment was conducted in a farmer's orchard located at Deesa (Banaskantha, Gujarat) during 1993-94 to study the effect of sixteen-year-age severly chlorotic *kagzilime* trees (*Citrus aurantifolia*, Swingle)grown on loamy sand soil, through

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soil application of $FeSO_4$, FeO, elemental sulphur, sulphuric acid and calcium sulphate. All trees involved in this study were nearly uniform in vigour, shape and size of trees. The experimental soil was sandy mixed hyperthermic family of Typic Ustipsamments having organic matter 1.04%, pH 7.8, EC 0.17 dSm^{-1}, available sulphur 8.9 ppm and DTPA extractable Fe 7.36 ppm.

The treatments were — three levels of iron as $FeSO_4$ 7 H_2O (20% Fe) at the rates of 36, 72 and 108 g Fe/tree (IS_{10}, IS_{20}, IS_{30}, respectively), - three levels of iron as FeO (70% Fe) at the rates of 36, 72 and 108 g Fe/ tree (IO_{10}, IO_{20}, IO_{30}, respectively), - two levels of sulphur as elemental sulphur (80% S) at the rates of 180 and 1800 g S/tree (ES_{50}, ES_{500}, respectively), - two levels of sulphur as sulphuric acid (30% S) at the rates of 719 and 1439 g S/tree (SS_{200}, SS_{400}, respectively), - two levels of sulphur as $CaSO_4$ 2 H_2O (13.6% S) at the rates of 180 and 360 g S/tree (CS_{50}, CS_{100}, respectively), control (untreated trees with Fe or S) but applied recommended 500 g N + 500 g P_2O_5 + 500 g K_2O and 50 kg farmyard manure per tree designated as RFM, - control (untreated trees with Fe or S) but applied 50 kg farmyard manure per tree designated as RM and absolute control (untreated trees) no NPK and FYM or treatment AC. The requisite quantities of fertilizers were applied once in a season (August, 1993). The recommended dose of N, P_2O_5 and K_2O (500 g each) was applied to each tree in 3 equal splits during August, October and February. The experiment was planned in a rendomized block design having two replications each of one tree.

Fruit yield was recorded in 7 pickings. Uniform fruits were selected for assessing quality parameters (AOAC, 1975).

TABLE 1

Effect of source and rate of iron and sulphur carriers on yield and per cent decrease in chlorosis of *Kagzilime* trees.

Treatment	*Fruit yield kg/tree**	*Number of fruit per tree**	*Per cent decrease in chlorosis with respect to initial scoring***
IS_{10}	6.934	160.5	27.3
IS_{20}	7.694	168.0	35.3
IS_{30}	9.600	202.5	47.8
IO_{10}	6.374	124.5	20.8
IO_{20}	7.672	193.0	30.6
IO_{30}	7.945	151.0	34.8
ES_{50}	7.380	150.0	21.3
ES_{500}	9.252	120.0	39.7
SS_{200}	9.173	147.0	38.1
SS_{400}	9.299	189.0	53.0
CS_{50}	7.144	121.5	25.0
CS_{100}	7.586	146.5	24.8
RFM	5.850	112.5	12.8
RM	5.338	93.0	10.8
AC	5.203	87.0	4.8
S. Em. ±	00.36	2.94	1.3
C. D. at 5%	1.086	8.93	4.1

* Total of seven pickings.

** Average of 7 periods of observations.

Four shoots of almost same physiological age and vigour on each side of the plant were tagged randomly on each test plant. These shoots were then used exclusively for recording the chlorosis scoring. The chlorosis was visually rated on the bassis of yellowing of the top leaves using the scale : 1 = no yellowing, 2 = slight yellowing, 3 = moderate yellowing, 4 = intense yellowing, 5 = severe yellowing with some necrosis. Observations on chlorosis were recorded on 45, 60, 90, 150, 180 and 240 days after soil application of treatments i.e., P_1, P_2, P_3, P_4, P_5 and P_6, respectively. The periodical samples were collected for analytical purpose.

The dried samples were subjected to sulphur estimation as per method suggested by Chaudhary and Cornfield (1966). Zinc, iron and manganese were estimated from acid extract on AAS-Simandzu-624 model. Magnesium was estimated by versenate method. Statistical calculations were carried out according to Snedecor and Cochran (1967).

RESULTS AND DISCUSSION

Fruit yield

Data given in (Table 1) indicated that IS_{30} gave significantly higher fruit yield than the untreated acidlime trees with Fe and S (RFM, RM & AC). However, it was at par with the yields of SS_{400}, ES_{500} and SS_{200}. The higher fruit yield obtained by these treatments was due to efficient control of the chlorosis (Table 1). All the Fe and S treatments have significantly higher number of fruits per tree as compared to the AC. The number of fruits per tree gave a highly significant correlation with fruit yield ($r = 0.715^{**}$). Higher level of ferrous sulphate (IS_{30}) had a direct role in increasing the concentration of Fe and S in plants. The higher efficiency of sulphuric acid (SS_{400}) might be attributed to decreased the chlorosis more effectively due to decrease in soil pH and acidulation of organic matter in soil. Higher level of elemental sulphur (ES_{500}) increased available S in soil and content of the plant. It also increased active iron and total iron concentration in the plant. increase in S content as a characteristic of the recovery of the chlorosis has been related in the literature to the role of S in promoting utilization of Fe in chlorophyll synthesis. Beneficial effects of increasing yield due to $FeSO_4$ @ 500 g/plant, 30 kg S/ha and sulphuric acid or elemental sulphur @ 900 g S/plant was endorsed (Khera *et al.*, 1985, Malavolta *et al.*, 1987 and Gajipara, 1988).

Fruit quality

The influence of soil treatments on *Kagzilime* fruit quality was presented in Table 2. The juice per cent was not significantly influenced due to Fe and S treatments whereas total soluble solids was affected significantly. The treatments RFM, IS_{10}, IS_{30}, IO_{10}, IO_{20}, IO_{30}, ES_{500}, SS_{200}, SS_{400} and CS_{100} recorded significantly higher total soluble solids than the control AC. These results were in agreement with those of Khera *et al.* (1985) who observed that total soluble solids of the citrus fruits increased due to soil application of $FeSO_4$ as compared to the untreated control AC.

The per cent increase in the ascorbic acid content of fruit in CS_{100}, ES_{500}, CS_{50}, IO_{10}, RFM, SS_{400}, SS_{200}, RM, IS_{30} treatments over the control AC varied from 66.7 to 130.2 per cent (Table 2). The improved growth and development of plants due to restoration of green leaves and consequent improved metabolic activity during fruit formation and maturity might have triggered processes contributing to quality parameters (Sharma and Reddy, 1984).

TABLE 2

Effect of source and rate of iron and sulphur carriers on fruit quality of *Kagzilime* trees.

Treatment	*Juice per cent*	*Total soluble soils (%)*	*Assorbic acid content (mg/100 ml juice)*
IS_{10}	34.75	6.6	16.130
IS_{20}	39.05	6.3	18.955
IS_{30}	37.05	6.6	22.175
IO_{10}	45.45	6.6	26.615
IO_{20}	37.60	6.6	18.145
IO_{30}	39.35	6.7	20.565
ES_{50}	39.05	6.1	18.950
ES_{500}	40.90	6.8	27.820
SS_{200}	42.15	6.7	26.205
SS_{400}	36.40	6.8	26.210
CS_{50}	42.00	6.6	27.420
CS_{100}	42.35	6.9	30.645
RFM	45.80	7.1	26.610
RM	47.15	6.6	25.400
AC	33.05	5.9	13.310
S. Em. ±	2.84	0.18	2.864
C. D. at 5%	NS	0.55	8.688

Leaf analysis

Total iron content of *Kagzilime* leaves was substantially increased over control due to treatments of iron (IO_{30}, IS_{30}, IS_{20} & IO_{20}) and sulphur (SS_{400}, ES_{500}, SS_{200} & CS_{100}) applied individually during 1993 season. However, the most effective treatments were SS_{400} and ES_{500}. Application of sulphuric acid (SS_{200}, SS_{400}), elemental sulphur (ES_{500}) and calcium sulphate (CS_{100}) in the soil significantly increased the total iron concentration in the leaf. This might be due to lowering of soil pH because of biological oxidation of these sulphur sources. The efficacy of gypsum was less than that of elemental sulphur and sulphuric acid due to its low solubility and lack of acidulating nature. Moreover gypsum treatment added low amount of sulphur (100 kg S ha^{-1}) to soil as compared to sulphuric acid. As expected, Fe sources also increased the total iron content in leaf.

The critical deficiency concentration (CDC) could be higher in the fast-growing meristematic and expanding tissues, in the range of 200 ppm total iron (Haussling *et al.*, 1985). Reddy and Sharma (1982) reported that CDC for chlorotic leaves of acidlime varied from 38 to 275 ppm with an average of 141.30 ppm, while the healthy leaves had 90 to 315 ppm with an avarage of 209.65 ppm. The total Fe concentrations given in Table 3 were of top leaves and based on these references the control values can be rated as CDC and the recovery of the chlorosis can said to be related to increase in total Fe *per se*. The soil was sufficient in available Fe, still these was distictly more total Fe content in the healthy leaves as compared to the chlorosis leaves showed a positive role of total Fe content in the leaves as a cause of the chlorosis.

Elemental sulphur (ES_{500}) recorded the maximum value of leaf sulphur and it was at par with the treatments SS_{400} and SS_{200}. It was followed by CS_{100}. The positive response of sulphur in leaf due to sulphur sources applied in soil might be due to low availability of sulphur in the soil (8.95 ppm of Ca $(H_2PO_4)_2$ extractable S). The findings were confirmed by UL Haq

TABLE 3

Sulphur and iron concentration of *Kagzilime* leaves as influenced by source and rate of iron and sulphur application in soil.

Treatment	*Sulphur content (S %)*				
	P_2	P_4	P_5	P_6	*Mean*
IS_{10}	0.081 (159)	0.189 (146)	0.140 (250)	0.102 (261)	0.128 (204)
IS_{20}	0.090 (102)	0.206 (175)	0.245 (311)	0.097 (314)	0.160 (225)
IS_{30}	0.116 (171)	0.238 (167)	0.243 (321)	0.108 (315)	0.176 (244)
IO_{10}	0.107 (127)	0.136 (140)	0.193 (245)	0.077 (260)	0.128 (193)
IO_{20}	0.122 (209)	0.102 (161)	0.213 (239)	0.096 (264)	0.133 (216)
IO_{30}	0.110 (144)	0.122 (179)	0.264 (263)	0.099 (423)	0.149 (252)
ES_{50}	0.196 (151)	0.179 (204)	0.257 (257)	0.092 (281)	0.181 (223)
ES_{500}	0.236 (207)	0.244 (222)	0.335 (296)	0.116 (366)	0.233 (272)
SS_{200}	0.221 (182)	0.215 (187)	0.262 (284)	0.101 (341)	0.200 (249)
SS_{100}	0.252 (202)	0.241 (223)	0.318 (306)	0.112 (364)	0.231 (274)
CS_{50}	0.140 (184)	0.147 (98)	0.197 (219)	0.096 (325)	0.145 (207)
CS_{100}	0.193 (184)	0.208 (120)	0.257 (307)	0.097 (335)	0.189 (237)
RFM	0.131 (127)	0.109 (90)	0.317 (213)	0.101 (208)	0.165 (160)
RM	0.148 (147)	0.134 (93)	0.307 (231)	0.084 (319)	0.168 (197)
AC	0.088 (135)	0.142 (98)	0.206 (191)	0.071 (232)	0.127 (164)
Mean	0.149 (162)	0.174 (154)	0.250	0.097	
		Period (P)	Treatment (T)	P x T	
	S. Em. ±	0.005 (8)	0.012 (19)		0.019 (30)
	C. D. at 5%	00.014 (22)	0.036 (56)		0.055 (NS)

Figures in parentheses indicated total iron concentration of *kagzilime* leaves in ppm.

and Carlson (1993) who reported increase in S content in fresh prune leaf when S was applied to soil through different sources of S.

The leaf samples of the control treatment contained S in the range of 0.086 to 0.206 per cent in different periods with an avarage of 0.127 per cent. CDC in acidlime for S was reported by 0.2 per cent (Bennett, 1993). Thus, nutritional status of the control trees can be stated as S deficient. Sulphur containing treatments SS_{400}, IS_{30}, ES_{500} and SS_{200} significantly synthesis, in comparison to control. These treatments had also significantly increased Mg, S, Mn, Zn and total Fe content in leaves. Thus it can be stated that with increased availability of sulphur there was restoration of nutrient balance in leaves, which favoured increased turnover of Fe^{2+} ions for use in chlorophyll synthesis. Sahu and Singh (1987) also reported that sulphur

TABLE 4

Nutrient contents of *Kagzillme* leaves as affected by source and rate of iron and sulphur application in soil.

Treatment	*ppm* Fe^{2+}*	*%* *Mg*	*ppm* *Mn*	*ppm* Zn
IS_{10}	20.68	0.68	19.15	16.80
IS_{20}	19.79	0.63	14.68	17.28
IS_{30}	20.46	0.56	12.40	17.24
IO_{10}	22.67	0.52	16.49	18.47
IO_{20}	21.72	0.55	14.10	19.16
IO_{30}	20.89	0.67	15.95	20.81
ES_{50}	19.42	0.63	17.26	20.25
ES_{500}	21.82	0.58	19.90	20.34
SS_{200}	21.67	0.59	16.84	17.86
SS_{400}	23.62	0.55	24.56	20.99
CS_{50}	20.73	0.46	12.65	17.38
CS_{100}	22.46	0.65	14.07	16.64
RFM	15.34	0.53	14.20	16.59
RM	14.49	0.53	16.28	17.04
AC	10.81	0.41	13.09	13.22
S. Em. ±	0.69	0.03	1.39	0.88
C. D at 5%	2.11	0.09	4.21	2.68

* Nutrient content of *Kagzilime* leaves from the average of P_2, P_4, P_5 & P_6 periods.

application created a balanced nutrition environment and thus kept iron physiologically active.

Magnesium content in *Kagzilime* leaves increased significantly in IS_{10}, IO_{30}, IO_{20}, CS_{100}, IS_{20}, ES_{50} and SS_{200} than the untreated control AC. The Mg content was higher in the soil receiving iron and sulphur treatments than the control because of alleviation of chlorosis in treated leaves. These results are in accordance with those obtained by Tropea *et al.* (1984) and Fernandez-Lopez *et al.* (1993) in citus who observed that Mg content in healthy leaves was higher than chlorotic leaves.

The Mn contents averaged over the four periods showed that SS_{400} recorded significantly higher value (Table 4). Next to SS_{400}, ES_{500}, IS_{10} and ES_{50} registered higher values of Mn. The effect of SS_{400} and ES_{500} in distinctly increasing the Mn content can be attributed to its lowering of soil pH and Increasing Mn concentration in soil. These treatments caused only a marginal increase in

Mn content which coincided with the increase in Fe content in leaf there by maintaining Fe : Mn ratio favourable for alleviation of iron chlorosis.

Leaf contents of Zn increased significantly by all treatments used when compared to the untreated trees (AC). The higher response was obtained by the treatments SS_{400}, IO_{30}, ES_{500}, ES_{50}, IO_{20} and IS_{10}. Since there was no Zn deficiency symptoms, the nutritional status of the plants with reference to Zn may be considered as normal. The increase in Zn content in leaf due to S and Fe treatments can be attributed as a consequence of alleviation of the chlorosis and overall improvement in growth of the plants (Dhingra and Kanwar, 1963).

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